STRENGTH CHARACTERISTIC STUDY
OF
FLY ASH COMPOSITE MATERIAL

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

MINING ENGINEERING

By

MANAS KUMAR SAHOO

ROLL NO: 107MN017

DEPARTMENT OF MINING ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA-769008
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Under the Guidance of

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ABSTRACT

Nearly about 67% of the total energy consumption in the country is fulfilled by coal as it is one of the primary sources of energy. India has one of the largest reserves of coal in the world. Indian coal has high ash content and low calorific value. The reserves are likely to last over another 100 years as the rate of coal extraction is increasing. The energy derived from coal in India is about twice that of energy derived from oil, as against the world, where energy derived from coal is about 30% lower than energy derived from oil. Most of the country's total installed power generation capacity is thermal. Coal-based generation is 90%. Thermal power stations, besides several captive power plants use coal and produce large quantities of fly ash. High ash content (30% - 50%) coal contributes to these large volumes of fly ash. The country's dependence on coal for power generation is increasing and so the production of fly ash will be more. Fly ash causes air, water and soil pollution when it is exposed to environment. This project report is an attempt to find a suitable utilization for a particular fly ash sample depending upon its geotechnical properties. The area required for disposing fly ash will be minimised and so damage to the environment will be minimum. In this project various geotechnical experiments were carried out on fly ash samples. Some of them are Tensile strength study, Unconfined compressive strength study etc. Based on the results obtained from these experiments, a suitable use for the fly ash is ascertained. Fly ash composite material (FCMs) was developed from captive power plant of NALCO, Angul, Odisha, India. The main constituents of the composite are:

1. Fly ash   2. Lime

Compressive and tensile strength were determined from the FCMs after 7, 14, 21 days of curing time. Different samples were taken with different percentages of lime (i.e. 5, 10, and 15 %) with fly ash and their properties were studied. The results from these above experiments helped in determining the potential of the fly ash for use, in manufacture of bricks, in highway embankments, as an aggregate material in Portland cement, filling of low lying and mine void areas etc. Composite material made of fly ash is subject to a variety of different loading conditions, and so different types of stresses develop. Based on the different strength of composites it can be used in various geotechnical applications like construction of roads, Embankment, dams and reservoirs and mine filling.

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CHAPTER 1

INTRODUCTION

BACKGROUND

OBJECTIVE

EXPERIMENTAL STUDY PLAN

CHAPTER: 01
INTRODUCTION

Thermal power stations use pulverized coal as fuel generates large quantities of fly ash as by-product. There are about 125 thermal power plants in India, which form the major source of fly ash in the country (Kumar and Singh, 2006). With the commissioning of super thermal power plants and with the increasing use of low grade coal of high ash content, the current production of fly ash is about 120 Million tonnes per year and is expected to reach around 170 Million tonnes by 2012 A.D (Kumar and Singh, 2006). This has posed a serious disposal and ecological problem in addition to occupying a large tract of scarce cultivable land. Although the beneficial use of fly ash in concrete, brick making, soil stabilization treatment and other applications have been recognized, only a small quantity of the total fly ash is being utilized in our country currently in such applications.

1.1 ASH FROM COAL COMBUSTION

The quality of coal depends upon its rank and grade. The coal ranks are arranged in an ascending order of carbon contents is:

Peat <Lignite < sub-bituminous coal< bituminous coal < anthracite

Indian coal is mostly sub-bituminous rank followed by bituminous and lignite (brown coal). The ash content in Indian coal ranges from 35 % to 50 %. The coal properties including calorific values differ depending upon the colliery location. The calorific value of the Indian coal (~ 15 MJ/Kg) is less than the normal range of 21 MJ/kg to 33 MJ/kg (gross). There are generally five categories of coal ashes available from thermal power stations. Those are:

Dry fly ash – It is collected from different rows of electrostatic precipitators in dry form. The fly ash is produced from the burning of pulverized coal in a coal-fired boiler. It is a fine grained, powdery particulate material in nature. It is carried through the flue gas and collected from the flue gas by means of electrostatic precipitators, bag-houses, or mechanical collection devices such as cyclones. Fly ash is the finest of coal ash particles. It is transported from the combustion chamber by exhaust gases. Fly ash is the fine powder produced from the mineral matter present in coal, plus a small amount of carbon that remains due to incomplete combustion. Fly ash is generally light tan in colour and consists mostly of clay-sized and silt-sized glassy spheres. This gives fly ash to a consistency somewhat like talcum powder.

Properties of fly ash vary with coal composition and plant operating conditions. Fly ash can be referred as either pozzolanic or cementitious. A cementitious material is one that hardens when mixed with water. A pozzolanic material also hardens when mixed with water but only after activation with an alkaline substance such as lime. Due to cementitious and pozzolanic properties of fly ashes they are used for replacement of cement in concrete and many other building applications.

Bottom ash –It is collected at the bottom of the boiler furnace and is characterized by better geotechnical properties. Coal bottom ash and fly ash are different physically, minerologically and chemically. Bottom ash is a coarse, granular, incombustible by-product that is collected from the bottom of the furnaces that burn coal for the generation of steam, the production of electric power or both. Bottom ash is coarser than fly ash, and grain sizes varying from fine sand to fine gravel. The type of by-product produced depends on the type of furnace used to burn the coal.

Pond ash – Bottom ashes and Fly ash are mixed together with water to form slurry which is pumped to the ash pond area. In the ash pond the ash gets settled and excess water is poured out. This deposited ash is called pond ash.

Boiler slag: Boiler slag is coarser than conventional fly ash and is formed in cyclone boilers, which produce a molten ash that is cooled with water. Boiler slag is generally a black granular material. It can be used in numerous engineering applications.

FGD gypsum: Flue Gas Desulfurization (FGD) gypsum is also known as scrubber gypsum. FGD gypsum is the by-product of an air pollution control system that removes sulphur from the flue gas in calcium based scrubbing systems. It is produced by employing forced oxidation in the scrubber and is composed mostly of calcium sulphate. FGD gypsum is most commonly used for agricultural purposes and for wallboard production.

1.2 ENVIRONMENTAL IMPACTS OF FLY ASH

The World Bank has cautioned India that by 2015, disposal of coal ash would require 1000 sq. km. of land. Since coal currently accounts for 70% of power generation in the country, there is a need of new and innovative methods for reducing impacts on the environment. The problem with fly ash lies in the fact that not only does its disposal require large quantities of land, water and energy, its fine particles, if not managed well, can become airborne. Currently more than 120 million tonnes of fly ash are being generated annually in India, with

65000 acres of land being occupied by ash ponds. Such a huge quantity does pose challenging problems, in the form of land use, health hazards and environmental damages.

Hazards

Due to physical characteristics and large volumes generated, fly ashes pose problems like:

1. It is very difficult to handle the material in dry state because it is very fine and readily air borne even in mild wind.
2. It disturbs the ecology of that region, becomes source of soil, air and water pollution.
3. Long inhalation of fly ash causes fibrosis of lungs, silicosis, pneumonitis bronchitis etc.
4. Flying fine particles of ash poses problems for living near power stations, corrode structural surfaces and affect horticulture.
5. Ultimate settlement of fly ash particles over many hectares of land in the vicinity of power station brings about perceptible degeneration in soil characteristics.

1.3 GOAL

The basic aim of this project is to evaluate the strength potential of fly ash with lime & water. The aim has been achieved through covering the following specific objectives.

1.4 OBJECTIVES:

The above goal was achieved with the following specific objectives.

1. Investigating the engineering properties and characteristics of the fly ash samples collected.

2. Investigating the strength gain of composite material aspects associated with the fly ash specimen collected.

3. Establishment of better suitable combinations of fly ash- lime compositions for compressive and tensile strength test under laboratory scale/conditions.

1.5 EXPERIMENTAL STUDY PLAN

To achieve the objectives outlined above, the study plan was divided into the following stages.

i. Collection of the fly ash samples: Fly ash samples were collected from NALCO THERMAL POWER STATION, Angul, Odisha, India.

ii. Collection of data: To carry out proper investigation of the strength characteristics of fly ash and for the fulfillment of the objectives mentioned above various necessary data & literatures were collected from different books, journals & internet.

iii. Preparation of the samples for testing: Samples of sizes 100 mm. × 50 mm. have been prepared taking mixtures of fly ash and lime.

iv. Tests performed: Various strength experiments e.g. Brazillian test, UCS tests were carried out for the prepared samples.

CHAPTER 2

LITERATURE REVIEW

GENERATION

CLASSIFICATION

PRODUCTION

TRANSPORTATION

CHARACTERIZATION OF FLY ASH

UTILIZATION

CHAPTER: 02
LITERATURE REVIEW

2.1 WHAT IS FLY ASH?

Fly ash is one of the residues generated in coal combustion facilities, and comprises the fine particles that rise with the flue gases.

2.2 WHERE DOES FLY ASH COME FROM?

Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately gets ignites, generates heat and produces a molten mineral residue. Boiler tubes extract heat from the boiler, cool the flue gases and cause the molten mineral residue to harden and form ash. Coarse ash particles, called as bottom ash or slag, fall to the bottom of the combustion chamber, and the lighter fine ash particles, termed as fly ash, remain suspended in the flue gas. Before exhausting the flue gas, fly ash is removed by particulate emission control devices, such as filter fabric bag houses or electrostatic precipitators.

2.3 PRODUCTION OF FLYASH

Fly ash is produced from the combustion of pulverized coal in industrial boilers or electric utility boilers. There are four types of coal-fired boilers: (i) pulverized coal (PC), (ii) stoker-fired, (iii) cyclone, and (iv) fluidized-bed combustion (FBC) boilers. The PC boiler type is the most widely used, especially for generating large electric units. The other boilers are more commonly used in industrial or cogeneration facilities. Fly ash is collected from the flue gases by using electrostatic precipitators (ESP) or in filter fabric collectors. The physical and chemical characteristics of fly ash depend on (i) combustion methods, (ii) coal source, and (iii) particle shape.

2.4 TYPES OF BOILERS

In general, there are three types of coal-fired boilers used in electric utility industry. They are as follows:

- Dry - bottom boilers
- Wet – bottom boilers
- Cyclone furnaces

The dry-bottom furnace is the most common type of coal burning furnace.

- When pulverized or powdered coal is combusted in a dry–ash, dry-bottom boiler, about 80% of all the ash leaves the furnace as fly ash, entrained in the flue gas.
- When pulverized coal is combusted in a wet bottom (or slag-trap) furnace, about 50% of the ash is retained in the furnace, and the other 50% being entrained in the flue gas.
- In a cyclone furnace, crushed coal is used as a fuel. 20 to 30 % leaves the furnace as dry ash and rest 70 to 80% of the ash is retained as boiler slag.

A general flow diagram of fly ash production in a dry-bottom coal-fired utility boiler operation is presented in Fig-2.1

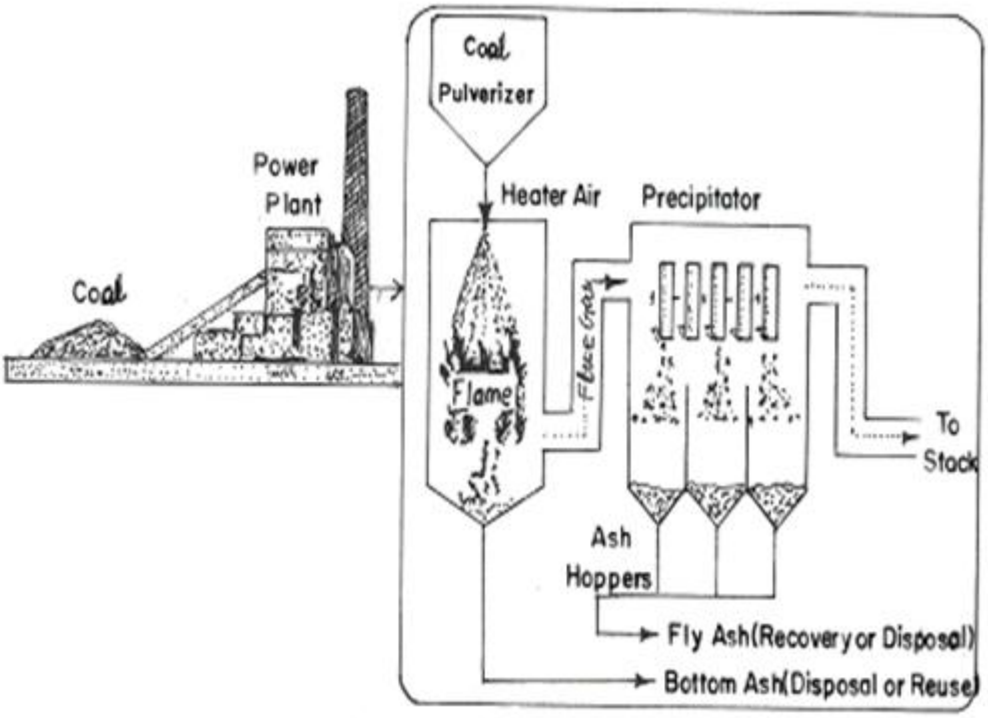

Figure No—2.1 A general flow diagram of fly ash production in a dry-bottom coal-fired utility boiler operation

2.5 FLY ASH CLASSIFICATION

There are basically two classes of fly ash as defined by ASTM C618 as:-

- Class F Fly ash
- Class C Fly ash

Differences between these two classes are based on the amount of Calcium, Silicon, Aluminium, & Iron content in ash. Chemical property is largely influenced by the chemical content of fly ash. All fly ash don’t meet ASTM C618 construction standard, but no such standard for environment has been established so far.

Class F Fly ash

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 20%lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds. Alternatively, the additions of a chemical activator such as sodium silicate (water glass) to a Class F ash can lead to the formation of a geopolymer.

Properties:

- Most effectively checks heat gain during concrete curing and is therefore considered an ideal cementitious material in mass concrete and high strength mixes. For the same reason, Class F is the solution to a wide range of summer concreting problems.
- Provides sulphide and sulphate resistance equal or superior to Type V cement. Class F fly ash is often recommended for use where concrete may be exposed to sulphate ions in soil and ground water.

Class C Fly ash

Class C fly ash is produced normally from lignite and sub-bituminous coals and usually contains significant amount of Calcium Hydroxide (CaO) or lime (Cockrell et. al., 1970). This class of fly ash, in addition to having pozzolanic properties, also has some cementitious properties (ASTM C 618-99).

Properties:

- Most useful in “performance” mixes, pre-stressed applications, and other situations where higher early strengths are important.
- Especially useful in soil stabilization since Class C may not require the addition of lime.

2.6 TRANSPORTATION

Fly ash can be supplied in four forms:

Dry fly ash: This is the most commonly used method for supplying fly ash. Dry fly ash is handled in the same manner as Portland cement is handled. It is stored in sealed silos with the associated filtration and desiccation equipment or in bags.

Conditioned fly ash**:** In this method, water is added to the fly ash to enhance compaction and easy handling. The amount of water added is determined by the end use of the fly ash. It is widely used in aerated concrete blocks, grouts and specialist fill applications.

Stockpiled fly ash: Conditioned fly ash is not sold immediately. It is stockpiled and used at a later date. The moisture content of stockpiled ash is typically 10 to 15 %. This is used mainly in bulk grouting and large fill applications.

Lagoon fly ash*:* Some power stations pump fly ash as slurry to large Lagoons. These are then drained and when the moisture content of that deposited fly ash has reached to a safe level then it may be recovered. Lagoon fly ash can be used in similar applications as stockpiled & conditioned fly ash.

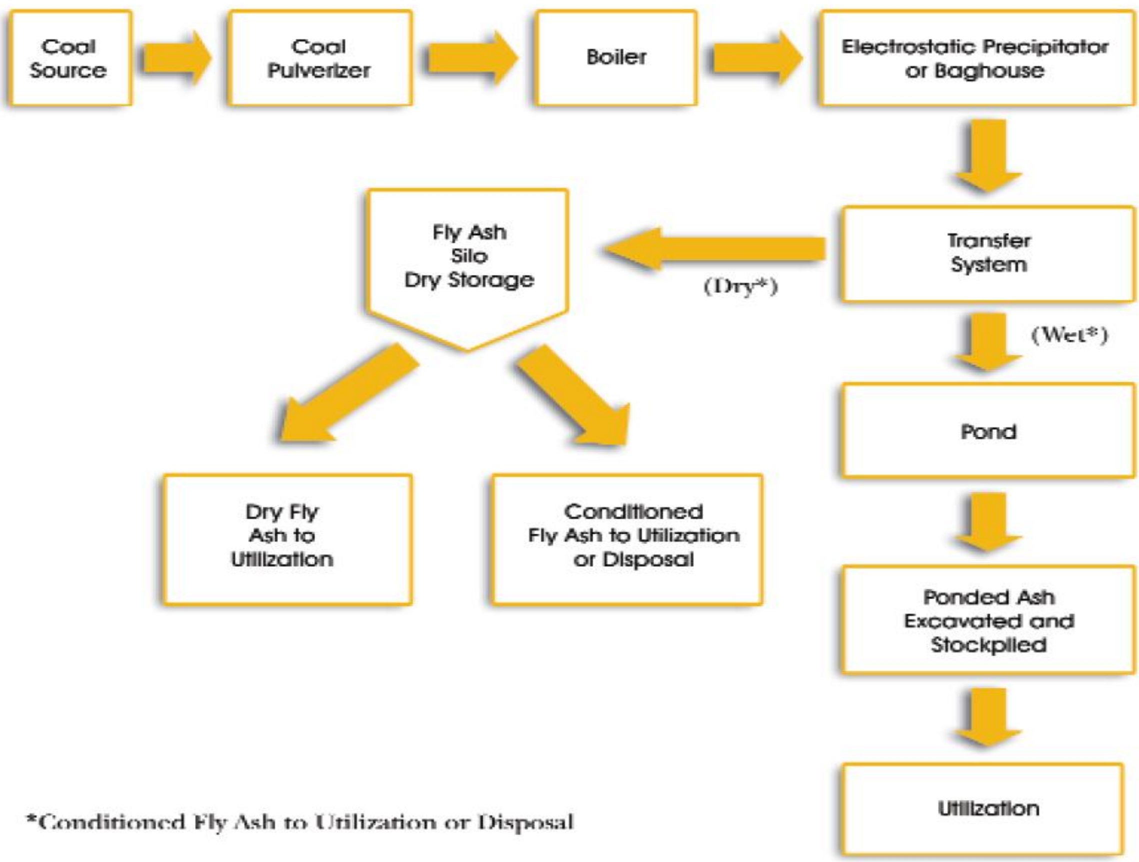

Figure2.2 Method of fly ash transfer

2.7 ENVIRONMENTAL BENEFITS

Fly ash utilization has significant environmental benefits:

(1) It increases the life of concrete roads and structures by improving concrete durability,

(2) It helps in net reduction in energy use and greenhouse gas.

(3) It can be used to replace or displace manufactured cement.

(4) Reduction in amount of coal combustion products as it is used in other purposes.

(5) Conservation of other natural resources and materials.

2.8 CHEMICAL COMPOSITION OF FLY ASH

The Fly ash particles are spherical in shape and ranges from 0.5micron to 100 micron. It contains mostly Silicon dioxide (SiO_2) in two forms crystalline and amorphous (both smooth and rounded), pointed and hazardous. Fly ash is generally heterogeneous, consisting of mixture of glassy particles as Quartz, Mullite, & Iron oxide. It contains toxins in significant amount. Silicon dioxide (SiO_2) both in crystalline form and amorphous form & Calcium oxide (CaO) are found in fly ash. It contains many toxic compounds which depend on the coal bed formation/makeup. It also include:- Arsenic (43.4ppm), Beryllium(5ppm), Boron(311ppm), Cadmium(3.4ppm), Chromium(136ppm), Chromium VI(90ppm), Cobalt(35.9ppm), Lead(56ppm), Manganese(250ppm), Mercury, Molybdenum, Selenium, Strontium, Thallium, Vanadium, etc.

TABLE -2.1 Chemical composition of Indian fly ash

Chemical composition	Percentage %
Silica (SiO_2)	49-67
Alumina (Al_2O_3)	16-29
Iron Oxide (Fe_2O_3)	4-10
Calcium Oxide (CaO)	1-4
Magnesium Oxide (MgO)	0.2-2
Sulphur (SO_3)	0.1-2
Loss of Ignition	0.5-3.0

TABLE -2.2 Normal ranges of chemical compositions for fly ash produced from different coal types (expressed as % by wt).

Component	Bituminous	Sub-bituminous	Lignite
SiO_2	20-60	40-60	15-45
Al_2O_3	5-35	20-30	10-25
Fe_2O_3	10-40	4-10	4-15
CaO	1-12	5-30	15-40
MgO	0-5	1-6	3-10
SO_3	0-4	0-2	0-10
Na_2O	0-4	0-2	0-6
K_2O	0-3	0-4	0-4
LOI	0-15	0-3	0-5

2.9 CHARACTERIZATION OF FLY ASH

Coal-based thermal power plants from all over the world facing serious problems of handling and disposal of the fly ash produced. The high ash content (30–50%) of the Indian coal makes this problem more complex. At present, about 85 thermal power stations produce nearly 120 million tonnes of coal ash per annum. For safe disposal of the fly ash without affecting the natural environment attempts are being made to utilize the fly ash rather than dumping it to somewhere else. The coal ash is utilized in geotechnical applications such as construction of embankments, as a sub-base material, as a backfill material, etc. in bulk only. For this, an in-depth study of the physical and chemical properties, and engineering and leaching behaviour are required.

2.9.1 PHYSICAL PROPERTIES

Physical properties help in classifying the coal ashes for engineering purposes and other engineering properties. Some of the properties discussed below are specific gravity, grain size distribution, index properties, free swell index and specific surface.

2.9.1.1 SPECIFIC GRAVITY

Specific gravity is one of the important physical properties which are needed for the use of coal ashes for geotechnical and other applications. Generally the specific gravity of coal ashes is around 2.0 but it can vary to a large extent (1.6 to 3.1). Because of the low value for the specific gravity of coal ash compared to soils, ash fills tend to result in low dry densities. The reduction in unit weight is advantage in the case of its use as a backfill material.The other application areas are reclamation of low-lying areas, embankments especially on weak foundation soils, etc.

The variation of specific gravity of coal ash is due to many factors such as gradation, particle shape and chemical composition. It is known that coal ash comprises mainly glassy cenospheres and some solid spheres. The reason for a low specific gravity could either be due to the presence of large number of hollow cenospheres, or the variation in the chemical composition, in particular iron content, or both. In most of the cases, fly ash has higher specific gravity compared to pond and bottom ashes of the same locality. Crushed particles show a higher specific gravity compared to the uncrushed portion of the same material.

2.9.1.2 GRAIN SIZE DISTRIBUTION

Grain size distribution shows weather a material is fine, coarse, well graded, or poorly graded, etc. and it also helps in classification of the coal ashes. Coal ashes are predominantly silt sized with some sand-size fraction. The pond ashes are consisting of silt-size fraction with some sand-size fraction. The bottom ashes are coarser particles consisting predominantly of sand-size fraction with some silt-size fraction. The coal ashes can be classified as sandy silt to silty sand based on the grain-size distribution. The coefficient of uniformity is in the range of 1.59–14.0.

2.9.1.3 INDEX PROPERTIES

Index properties are widely used in geotechnical engineering practices. Liquid limit is an important physical property used in classification and co-relating with engineering properties. Two methods (Percussion cup and falling cone methods) are popular for the determination of liquid limit of fine-grained soils, "Equilibrium water content under *Ko* stress method"a new method for determining liquid limit has been found to be effective for the determination of liquid limit of coal ashes. The proposed method is reasonably error free, simple, less time consuming and has good reproducibility. It is not suitable for class C fly ashes as it gains strength with time. The liquid limit values showed by coal ashes are due to their fabric and carbon content. It is not possible to carry out shrinkage limit tests since the ash pats collapse upon drying.

2.9.1.4 SPECIFIC SURFACE

The study of specific surface of fly ash is widely accepted to understand the physical and engineering behaviour of coal ash. Even though coal ashes are primarily silt/sand-sized particles and their specific surface is expected to be very low it is required for completeness and for use in certain cases.

2.9.1.5 Free swell index

The free swell test method proposed by Holtz and Gibbs is to estimate the swell potential suffers from certain limitations. Sridharan et al. modified the definition of free swell index itself to take care of the limitations. There is hardly any information about the free swell index of coal ashes in published literature. Experiments were carried out at IISc to study the free swell index of coal ashes. The results indicate that most (70%) of the coal ashes show negative free swell index due to flocculation. The free swell index is negligible since the clay-size fraction in coal ashes is very less,

2.9.2 CHEMICAL PROPERTIES

The chemical properties of the coal ashes mainly influence the environmental impacts that may arise out of their use/disposal as well as their engineering properties. The adverse impacts include contamination of surface and subsurface water with toxic heavy metals present in the coal ashes, loss of soil fertility around the plant sites, etc. P^H, TOTAL SOLUBLE SOLIDS, lime reactivity, Initial and final setting times.

2.9.2.1 P^H

The characteristics of Indian coal ashes show that fly ash has higher pH values compared to pond and bottom ashes. The fly ash having higher free lime and alkaline oxides shows higher pH values. The coal ashes are mostly alkaline, so they can be used in reinforced cement concrete which will be safe against corrosion.

2.9.2.2 TOTAL SOLUBLE SOLIDS

The presence of soluble solids is an important aspect during examination since the water soluble solids greatly influence the engineering properties. The solubility of nutrient elements such as calcium, sulphur, phosphorus, magnesium, iron, potassium and manganese affect the crop yield to a great extent. The solids generally range between 400 and 17600 ppm for fly ashes, 800 and 3600 ppm for pond ashes, and 1400 and 4100 ppm for bottom ashes.

2.9.2.3 Lime reactivity

The strength of fly ash generally increases with time due to pozzolanic reactions. For Pozzolanic reactions reactive silica and free lime contents are necessary. Lime reactivity is a property that depends on the proportion of reactive silica in coal ash. The pozzolanic reactivity of Indian fly ashes ranges between 11.4 and 52.90 kg/cm^2. The lime reactivity is generally high for coal ashes with high silica content. Fly ash has high lime reactivity as compared to bottom and pond ashes.

2.9.3 OTHER PROPERTIES

2.9.3.1 COMPACTION BEHAVIOUR

The density of coal ashes is an important parameter as it controls the strength, compressibility and permeability. Densification of ash improves the engineering properties. Unit weight of the compacted material depends on the amount, grain size distribution, plasticity characteristics, moisture content and method of energy application. The variation of dry density with moisture content of fly ashes is less as compared to that for a well-graded soil, though both having the same median grain size. The tendency of fly ash to be less sensitive to variation in moisture content than for soils could be explained by the higher air void content of fly ash. Soils normally have void (air) content ranging between 1 and 5% at maximum dry density, whereas fly ash contains 5 to 15%. The higher void content could tend to limit the build-up of pore pressures during compaction, thus allowing the fly ash to be compacted over a larger range of water content. Gray and Lin have described the engineering properties of compacted fly ash and have opined that properly compacted and stabilized fly ash has the requisite properties for use in highway sub-bases or load-bearing fills. The variation in specific gravity the compaction behaviour of soils and coal ashes is almost the same. Since the dry densities of coal ashes are less sensitive to compaction water content, the field compaction can be carried out at dry side of the optimum taking care of the dust problem. Good shearing resistance is available even at low densities; field compaction need not be constrained to achieve maximum dry density rather taking care of the construction difficulties.

2.9.3.2 CONSOLIDATION BEHAVIOUR

Compressibility characteristics of coal ash depend on its initial density, self-hardening characteristics, degree of saturation, and pozzolanic activity. Partially saturated ashes are less compressible compared to fully saturate ones. For coal ashes the primary consolidation gets over within a very short interval of time. The compression index is less in the case of partially saturated ashes which is due to capillary forces. Upon inundation, the capillary forces vanish and hence the compressibility is more for saturated samples.

2.9.3.3 PERMEABILITY BEHAVIOUR

Permeability is an important parameter for the designing of liners to contain leachate migration, dykes to predict the loss of water as well as the stability of slopes and as a sub-base material. The coefficient of permeability of ash depends upon the degree of compaction, grain size and pozzolanic activity. The fly ash shows lower permeability values if it contains more free calcium resulting in cementation leading to reduction in permeability. The bottom and pond ashes which are coarse grained and devoid of fines compared to fly ash have a higher value for permeability coefficient. The consolidation pressure also effect on the permeability. This spherical shape and uniform grain size of coal ash makes ash 5 to 10 times more permeable than soils having the same effective grain size. The permeability co-efficient "k" of compacted ash is around $8*10^{-6 \text{ to}}$ $7*10^{-4}$ cm/sec.

2.9.3.4 LEACHING BEHAVIOUR

Depending on the sources of coals used by thermal power plants, fly ash may contain various toxic elements. Due to serious environmental problems involved, the leaching of these toxic elements from ash ponds is gaining considerable importance. The leaching characteristics are highly variable and even within a given landfill site, leaching quality varies over time and space. Theis and Wirth have studied the sorptive behaviour of trace metals on fly ash in aqueous systems. Dudas, has conducted a long-term leaching experiment to determine the release of ion and weathering characteristics of fly ash. Weng and Huang have studied the treatment of industrial waste water containing heavy metals by fly ash and cement fixation.

2.10 ENVIRONMENTAL ASPECTS OF FLY ASH DISPOSAL

The environmental aspects of fly ash disposal aim for minimizing air and water pollution. Directly related to these type of concerns is the additional environmental goal of aesthetically enhancing ash disposal facilities. The ash produced from thermal power plants can cause all three environmental risks- AIR, SURFACE WATER AND GROUND WATER POLLUTION. The pathways of pollutant movement through all these paths are schematically represented in Fig-2.3.

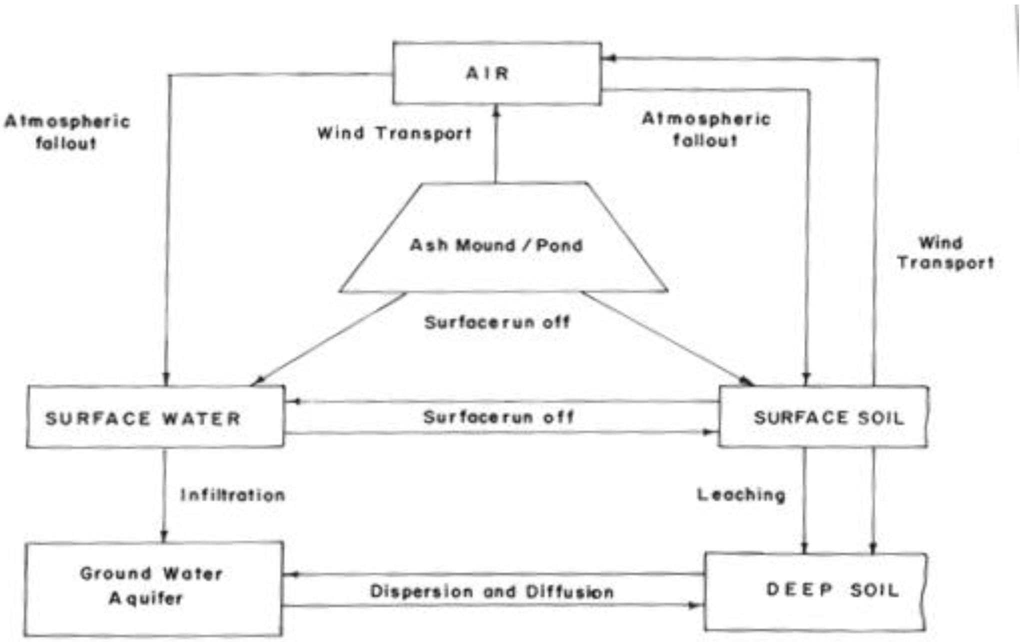

Fig No- 2.3 The pathways of pollutant movement

2.11 UTILIZATION OF FLY ASH IN CIVIL ENGINEERING WORKS

- Fly ash as Raw material for cement manufacture (for blended cement products)
- Fly ash in Embankment construction
- Fly ash use in Flexible pavements
- Fly ash use in concrete (pre-mixed concrete)
- Fly ash is used for making light weight aggregates.
- Use of Fly ash as landfill.
- Fly ash use for road stabilization
- Controlled low strength fills
- Asphaltic mineral fillers
- Light weight brick manufacture
- Building components : Fly ash based components for construction industry:

(a) **Pavement blocks**: These products are durable, economic, faster and easy construction, self-interlocking and Aesthetic.

(b) **Ceramic tiles**: Fly ash content up to 35%, less water absorption & firing shrinkage, less energy intensive (These products are developed by CGCRI, Ahmedabad).

(c) Wood substitute for doors and panels:

- These are 100% wood free,
- 5-7 times stronger than wood
- Resistant to weather, termite, fungus and fire (developed by RRL , Bhopal)
- Pilot plant operational at Pondicherry
- Product approved by CPWD and accepted by IIT, Delhi

(d) Fly ash granite (Granite substitute)

- Fly ash content 60%
- Good finish, properties comparable to natural granite
- Developed by BHEL corporate office, New Delhi

(e) PAINTS AND ENAMELS

- fly ash exhibits better extending properties (less oil absorption)
- Fly ash percentage : 30-40 % (in paints) , 18-22% (in enamels)
- Corrosion and abrasion resistant
- Durable

2.12 FLY ASH UTILIZATION IN MINES

- Mine void filling (underground)
- Reclamation of abandoned surface coal mines
- Neutralization of Acid Mine Drainage
- Stabilization of abandoned coal mines
- Haul road repair and maintenance in opencast coal mines.
- For oil and grease trap in the workshops where heavy earth moving machineries are maintained.
- For repair and maintenance of sedimentation ponds of coal handling plants.
- For surface – mine spoil reclamation
- Control of coal mine fire.

Considerable research findings and field applications are noted in the literature in terms of the utilization of fly ash and mill tailings for back filling.

2.13 AGRICULTURAL APPLICATION OF FLY ASH

2.13.1 Fly ash as herbicide

Finest fraction of the ash has also been used either as a herbicide or carrier of pesticide with encouraging results. Dusting of domestic kitchen ash over plants (including Tulsi) and vegetable crops (such as brinjal) drives away insects, is a common sight in rural homes of India. Such kitchen ash with high proportion of anhydrous oxides of alkalis and alkaline earth, such as Na_2O, K_2O,CaO and MgO, dehydrates (dehydrolyse) animals eating away the plant parts. Classified fly ash can similarly be used for the same purpose. Besides, 80% of the ash being glass, the fine splinters of glass on leaf surface when chewed is likely to damage the oral cavity and mandible of the chewing species, starving them to death. Even when swallowed, the splinters would damage food channel and destroy the insect in due course of time. Therefore alkali rich fly ash after suitable classification can be used as a herbicide. Thus with proper understanding of the various properties of fly ash and suitable modifications, fly ash can find extensive use in agricultural practices and ease the burden of accumulation in the backyard of coal based thermal power plants. Dusting of domestic kitchen ash over swampy and damp area during rainy season is also a common sight in rural homes and cow sheds of India. Such kitchen ash with high proportion of anhydrous oxides of alkalis and alkaline earth, such as Na_2O, K_2O, CaO and MgO, dehydrates (dehydrolyse) the damp, swampy and marshy area and keeps, the area free from water so that men and animals can feel comfortable because the insects, flies and mosquitoes cannot breed in those area and many diseases because of their bite can be eliminated. Classified fly ash can similarly be used for the same purpose.

2.14 ADVANTAGES OF ADDITION OF FLY ASH IN CONCRETE

- Increased (later) Compressive Strength
- Increased Workability
- Reduced the heat of hydration (CANMET, Canada found that 10 ft cubes had a temperature rise of only 35 deg Celsius vs. 65 deg using Portland cement)
- No leaching of Calcium Hydroxide crystals occurs on to the surface (those white patches)
- Increased Durability -(low Chloride Ion penetration, i.e. very low coulomb rating that further decreaseswith time).
- Decreased Permeability
- Reduced Sulfate Attack
- Decreased Bleeding & Segregation
- Reduced Drying Shrinkage

CHAPTER 3

METHODS AND MATERIALS

FLY ASH COMPOSITE CHARACTERIZATION

MOISTURE CONTENT

TRUE DENSITY

PREPARATION OF FLY ASH COMPOSITE MATERIAL

STRENGTH TESTS

CHAPTER: 03

METHODS and MATERIALS

This section summarises the procedures and materials used in performing the various tests of fly ash composite in order to utilize in Geotechnical Application like roads and Embankment, dams and reservoirs and mine filling. This section describes the fly ash characterization methods and the method for preparing Lime -fly ash mix specimens. Fly ash occupies huge disposal area and has a potential threat of local ground water and surface water pollution by leaching of metal. To mitigate the problem is to recycle the fly ash as a safe construction material and other purposes. Due to inherent self-hardening properties of fly ash it is used in different civil engineering applications. But it lacks adequate strength or durability. Suitable mixture is one of the methods to enhance the strength of the fly ash.

3.1 FLY ASH COMPOSITE CHARACTERIZATION

Fly ash composite characterization test were performed on the fly ashes that were investigated in this project. Tests included compressive strength, tensile strength. In addition to this moisture content and true density of fly ash were found.

3.2 MOISTURE CONTENT

Moisture is an important property of coal because all coals are mined wet. Groundwater and other external moisture is known as adventitious moisture and is readily evaporated. Moisture which is held within the coal itself is known as inherent moisture and is analysed quantitatively. Moisture may occur in four possible forms within coal:

- Surface moisture: water present on the surface of coal particles or macerals
- Hydroscopic moisture: water which is present by capillary action within the micro fractures of the coal
- Decomposition moisture: water which is held within the coal's decomposed organic compounds
- Mineral moisture: water which comprising part of the crystal structure of hydrous silicates such as clays.

Though fly ash is produced by combustion of coal still it contains some percentage of moisture.

Test procedure

About 1 gm of finely powdered of size (-212 micron) air-dried fly ash sample is weighed in a silica crucible and then placed it inside an electric hot air oven, where the temperature is maintained at $108^0 \pm 2^0$C. The crucible with the fly ash sample is allowed to remain in the oven for 1.5 hours and is then taken, cooled in desiccators for about 15 minutes and then weighed. The loss in weight is moisture (on % basis). Then calculation is done as per the following.

% moisture = Y−Z/Y−X

Where X= weight of empty crucible, gram

Y= weight of crucible + fly ash sample before heating, gram

Z= weight of crucible + fly ash sample after heating, gram Y−X= weight of fly ash sample, gram Y−Z= weight of moisture

Table: 3.1 moisture content of fly ash

Weight of empty crucible(gm)	**Weight of fly ash (gm)**	**Weight of crucible and fly ash before heating (gm)**	**Weight of crucible and fly ash after heating (gm)**	**Moisture content (%)**	**Average moisture content (%)**
1	35.069	36.070	36.044	2.59	2.78
2	40.519	41.523	41.495	2.78	
3	43.852	44.856	44.826	2.98	

3.3 TRUE DENSITY

True density of fly ash is the weight per unit volume of very finely powdered sample. Therefore, the volume of pore spaces and the interspaces is not included here.

Test procedure Take a measuring jar graduated in ml. clean it thoroughly with pure water. Take water into the flask up to certain level and note down its level (initial reading). Drop slowly 20 grams of the fly ash sample into the jar. Shake the jar for some time. Now note down the level of water in the jar (final reading). Repeat this for 3 samples. Divide the difference of the final and initial reading by weight of the sample to obtain true density.

Table: 3.2 True density of fly ash

SL. NO.	Amount of fly ash taken (gm)	Initial reading in (ml)	Final reading in (ml)	Difference in (ml)	True Density in (gm/cc)	Average true density
1	20	122	112	10	2	2.2
2	20	184	176	8	2.5	
3	20	151	142	2.12	2.12	

3.4 PREPARATION OF FLY ASH COMPOSITE MATERIAL

The fly ash is chosen for its availability in abundances well as its low lime content. On the basis of the literature review, different lime proportions (0, 5, 10, and 15) % of fly ash (by weight) was selected. The addition of lime increases the pozzolanic reactivity of fly ash containing insufficient free lime required for pozzolanic reaction with its reactive silica.

Things Required:

1. Fly ash about 20 Kg
2. Lime about 2 Kg
3. Digital weight Balance
4. Measuring Cylinder
5. PVC pipes of designate Length

STEPS IN PREPARATION

1. Fly ash about 410.4 gms was taken and required amount of lime (5, 10, 15 % of weight of sample) and water quantity (20 %) of weight of sample are thoroughly mixed by hand.
2. Then the composite was put inside the pipe. Adequate ramming was done with a rod for proper compaction.
3. Then it was kept inside a plastic mould for 24 hour.
4. The samples were cast to size of. 50 mm diameter and 100 mm length for compressive strength tests and 25 mm length and 50 mm diameter for tensile strength test.
5. The samples were taken out of mould and placed inside humidity control chambers for curing where the temperature was maintained at about 30°C ±1%.

The following mixes have been used in the investigation:

1. 95 FA+5L
2. 90FA+10L
3. 85 FA+ 15L
4. 100 FA+ 0L

FA-Fly ash

L-lime

3.5 STRENGTH TESTS:

3.5.1 UNIAXIAL COMPRESSION TEST:

Purpose: To determine the uniaxial compressive strength of Fly ash composite material

Procedure:

1. The test procedure is similar to the unconfined compression test for soil. The samples of L/D ratio is taken as 2:1.
2. Place the specimen on the base plate of the load frame.
3. Place a hardened steel ball on the bearing plate.
4. Adjust the centre line of the specimen such that the proving ring and the steel ball are in the same line.
5. Fix a dial gauge to the base plate to measure the vertical compression of the specimen.
6. Adjust the gear position on the load frame to give suitable vertical displacement.
7. Apply the load and record the readings of the proving ring dial and compression dial for every .25 mm compression.
8. Continue loading till failure is complete.

Fig No-3.1 Compression testing machine

3.5.2BRAZILLIAN TEST:

Purpose: To evaluate the tensile strength of fly ash composite material

Procedures:

1. The test procedure is similar to the tensile strength test for soils.
2. Specimens with length-to-diameter ratios (L/D) of 2.5 are placed in a compression loading machine shown in fig- with the load platens situated diametrically across the specimen.
3. Adjust the centre line of the specimen such that the proving ring and the steel ball are in the same line.
4. Fix a dial gauge to the base plate to measure the vertical compression of the specimen.
5. Adjust the gear position on the load frame to give suitable vertical displacement.
6. Apply the load and record the readings of the proving ring dial and compression dial for every .10 mm compression.
7. Continue loading till failure is complete.

CHAPTER 4

RESULTS AND DISCUSSION

CHAPTER-04
RESULTS AND DISCUSSION

4.1 COMPRESSIVE & BRAZILLIAN TENSILE STRENGTH

The determination of compressive and tensile strength of the prepared samples was carried out as per standard practiced. The following table shows the compressive and Brazillian tensile strength of various samples after testing.

Table No 4.1 Compressive & Brazilian tensile strength result

Samples	Curing period (days)	UCS (Mpa)	BrazillianTensile Strength(kpa)
100 FA+0L	7	0.0691	0
	14	0.0747	0
	21	0.0767	0
95 FA+5 L	7	0.163	84.9
	14	0.211	107.3
	21	0.223	111.7
90 FA+10 L	7	0.212	98.3
	14	0.233	110.5
	21	0.248	116.2
85 FA+15 0 L	7	0.236	108.3
	14	0.301	134.1
	21	0.325	139.4

4.1.1 RESULTS

The following are some stress & strain graphs which gives the failure behaviour of samples.

7 DAYS CURING UCS

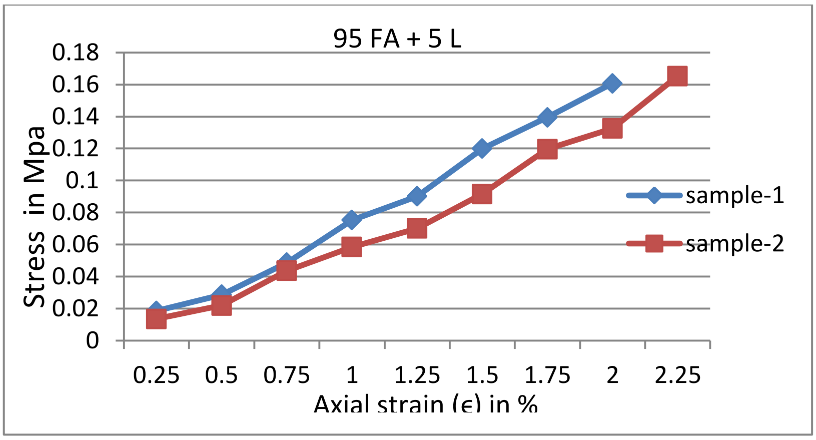

Fig No-4.1 Graph showing plot between stress and strain with 5 % lime of 7 days cured UCS sample.

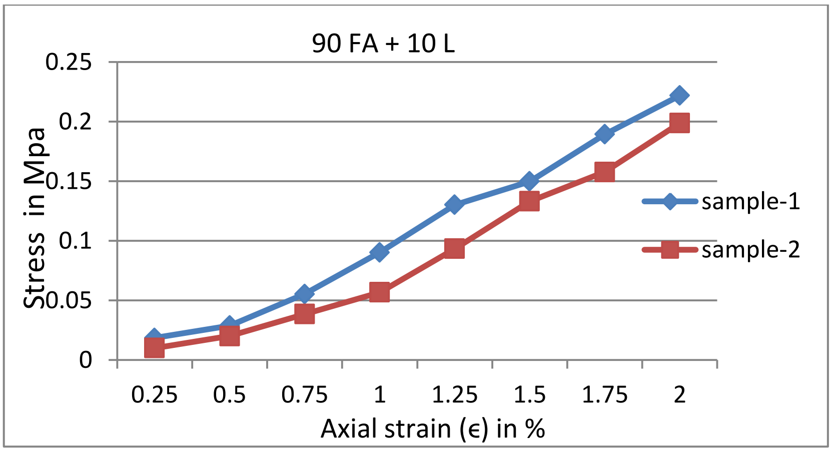

Fig No-4.2 Graph showing plot between stress and strain with 10 % lime of 7 days cured UCS sample.

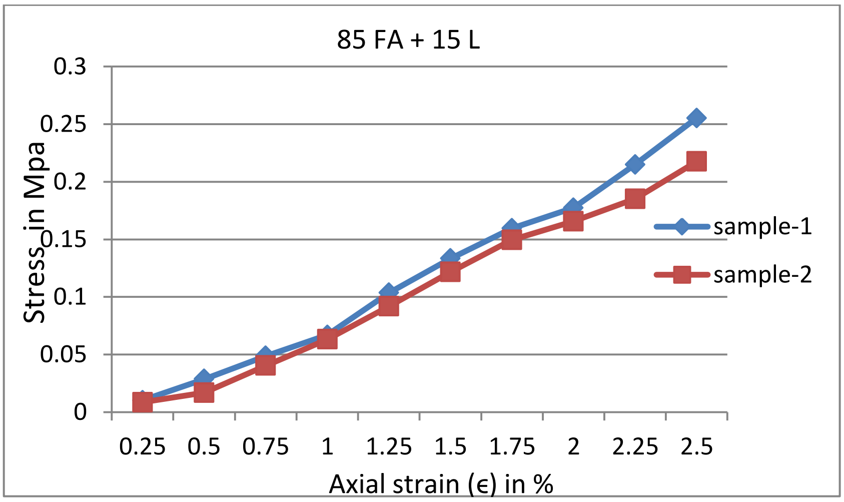

Fig No-4.3 Graph showing plot between stress and strain with 15 % lime of 7 days cured UCS sample.

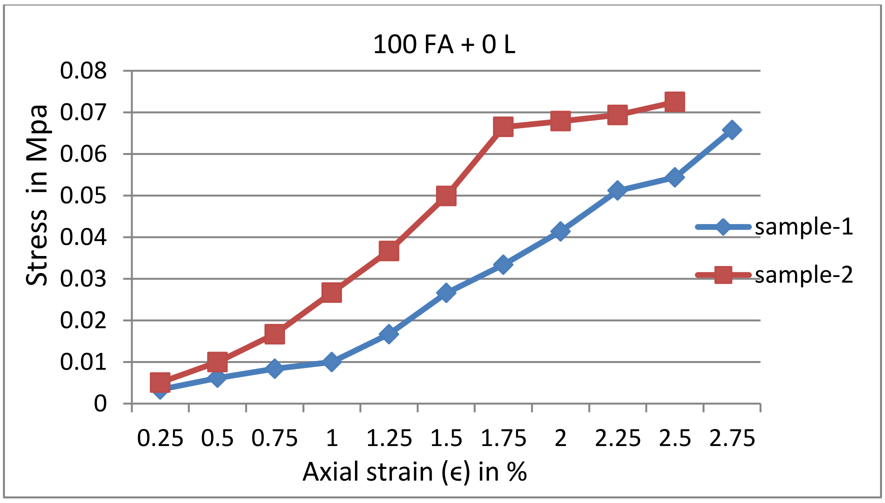

Fig No-4.4 Graph showing plot between stress and strain with no lime of 7 days cured UCS sample.

14 DAYS CURING UCS

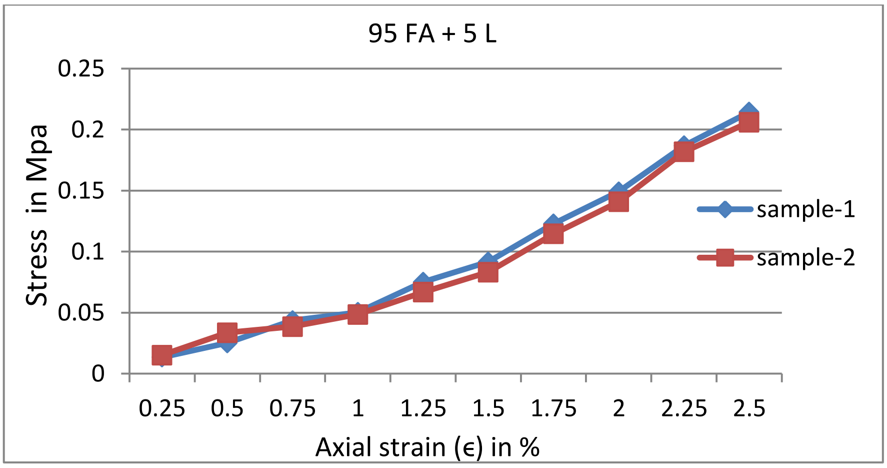

Figure No-4.5 Graph showing plot between stress and strain with 5 % lime of 14 days cured UCS sample

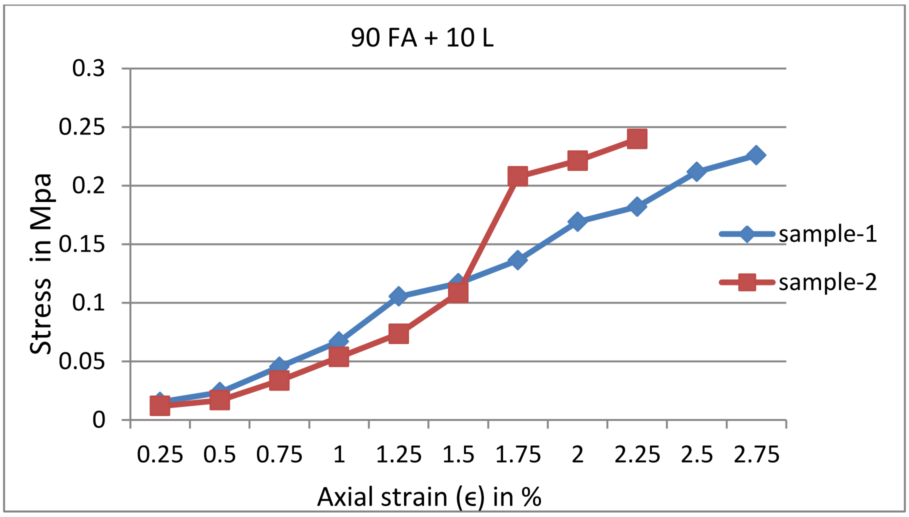

Figure No-4.6 Graph showing plot between stress and strain with 10 % lime of 14 days cured UCS sample

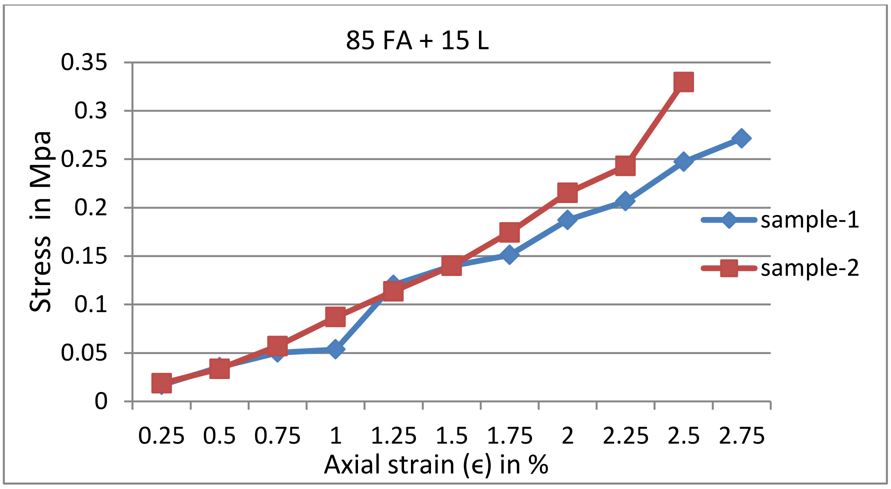

Figure No-4.7 Graph showing plot between stress and strain with 15 % lime of 14 days cured UCS sample

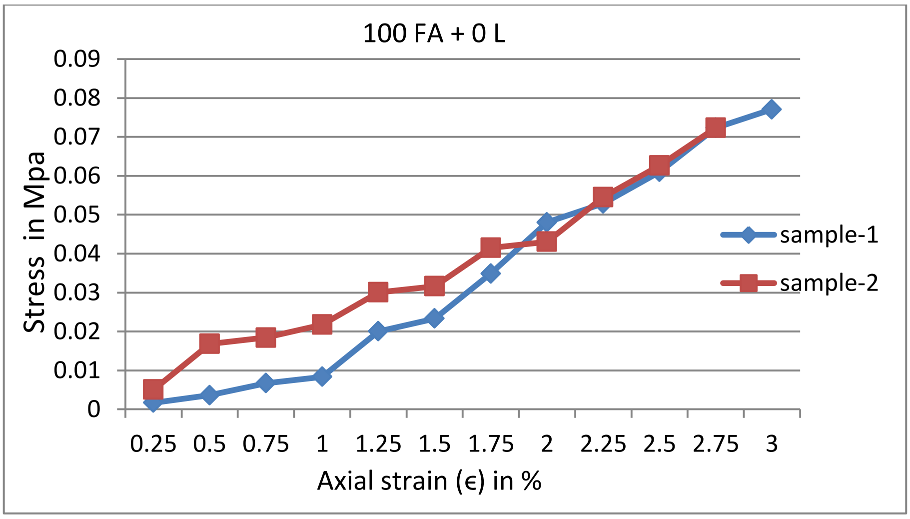

Figure No-4.8 Graph showing plot between stress and strain with no lime of 14 days cured UCS sample

<u>21 DAYS CURING UCS</u>

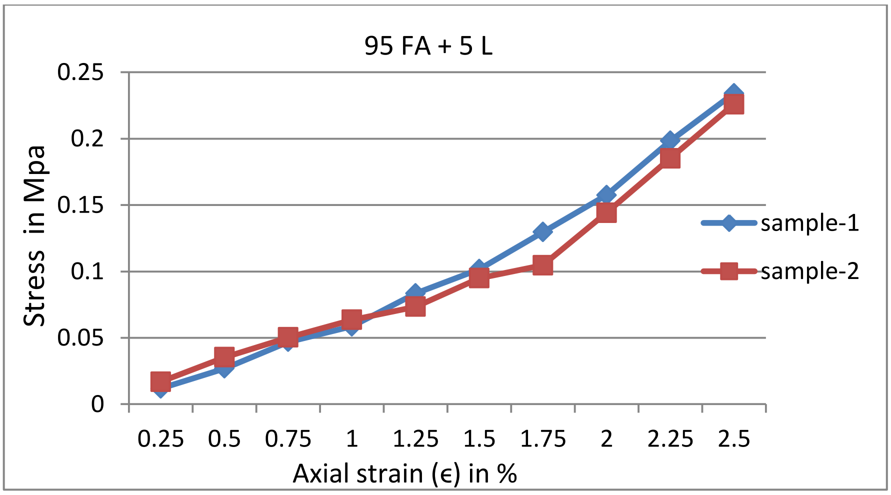

Figure No-4.9 Graph showing plot between stress and strain with 5 % lime of 21 days cured UCS sample

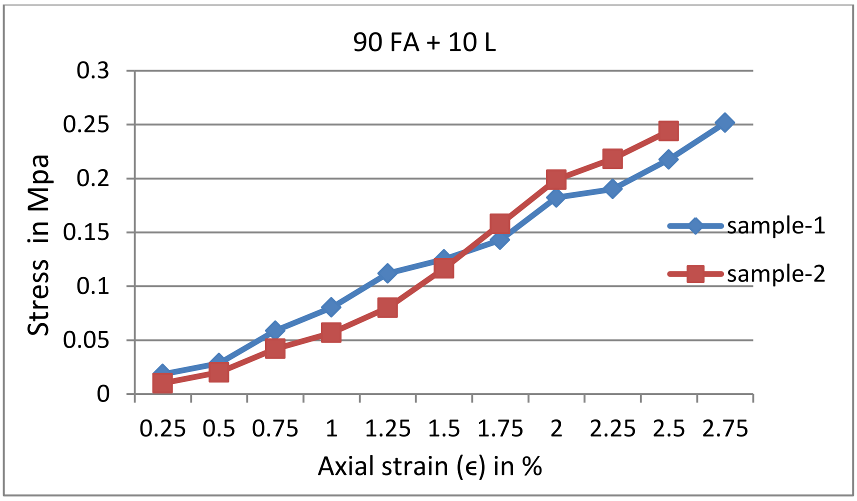

Figure No-4.10 Graph showing plot between stress and strain with 10 % lime of 21 days cured UCS sample

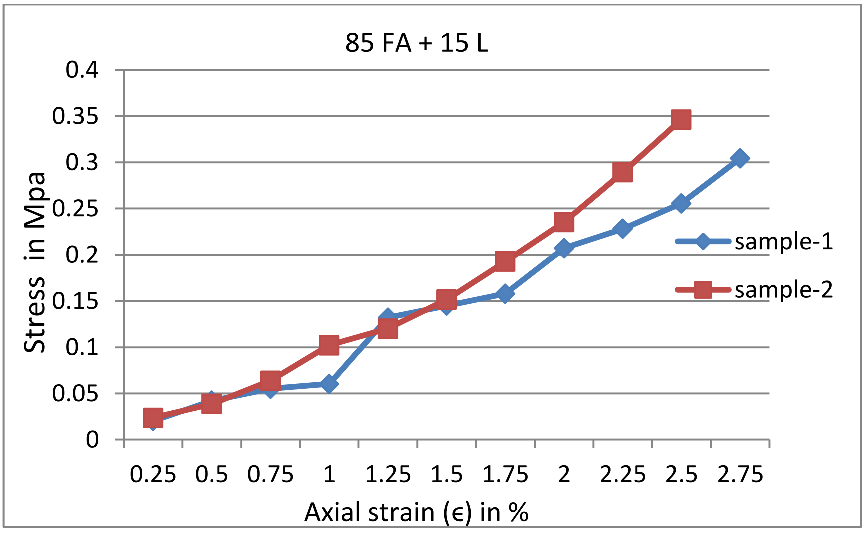

Figure No-4.11 Graph showing plot between stress and strain with 15 % lime of 21 days cured UCS sample

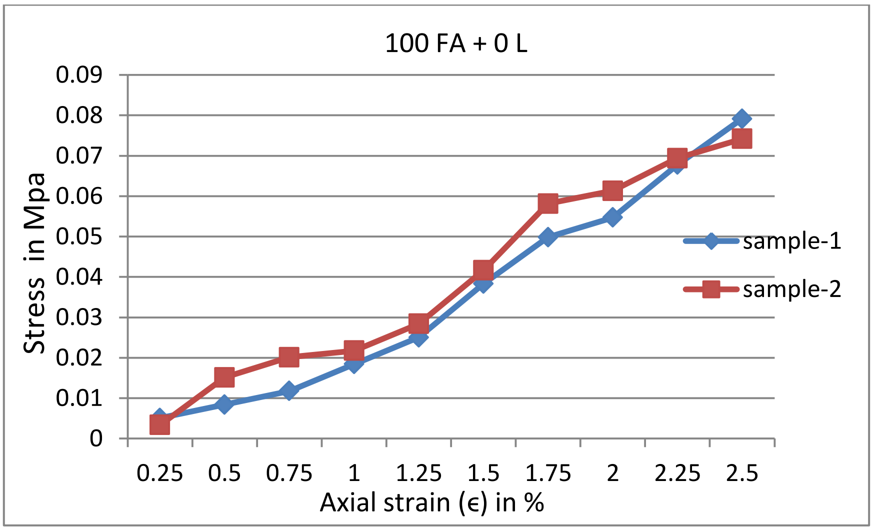

Figure No-4.12 Graph showing plot between stress and strain with no lime of 21 days cured UCS sample

BRAZILLIAN TENSILE STRENGTH TEST

7 DAYS CURING

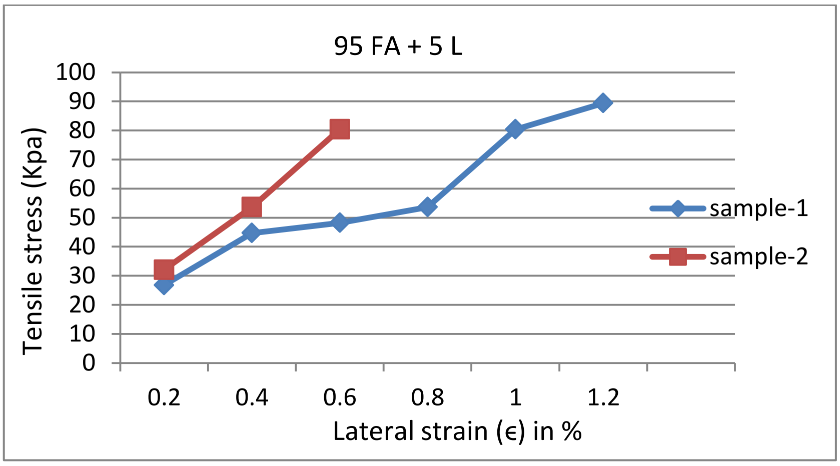

Figure No-4.13 Graph showing plot between stress and strain with 5 % lime of 7 days cured TS sample

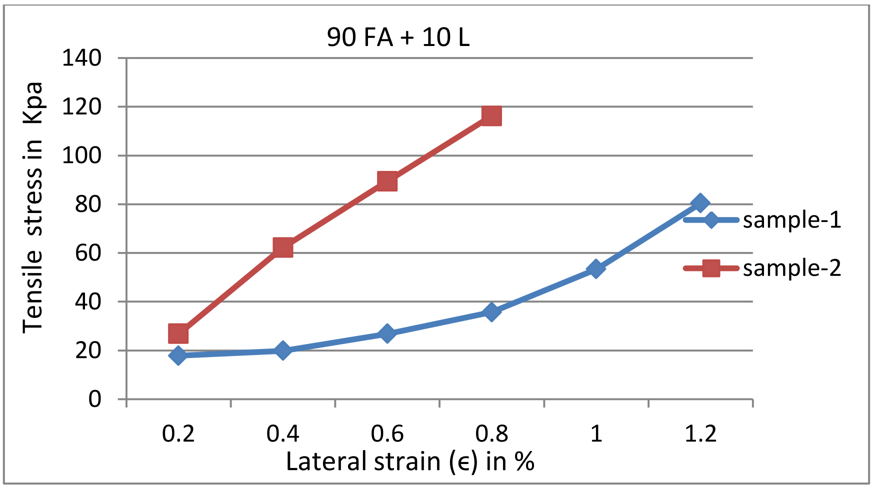

Figure No-4.14 Graph showing plot between stress and strain with 10 % lime of 7 days cured TS sample

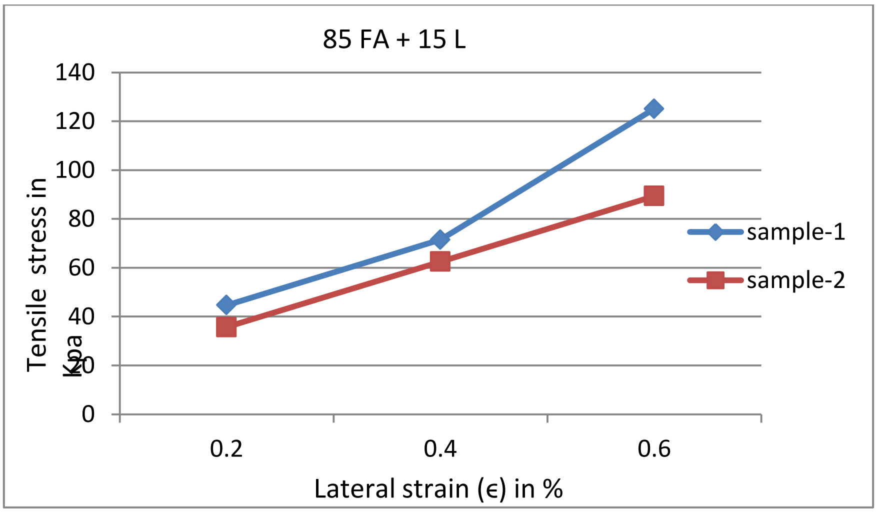

Figure No-4.15 Graph showing plot between stress and strain with 15 % lime of 7 days cured TS sample

14 DAYS CURING

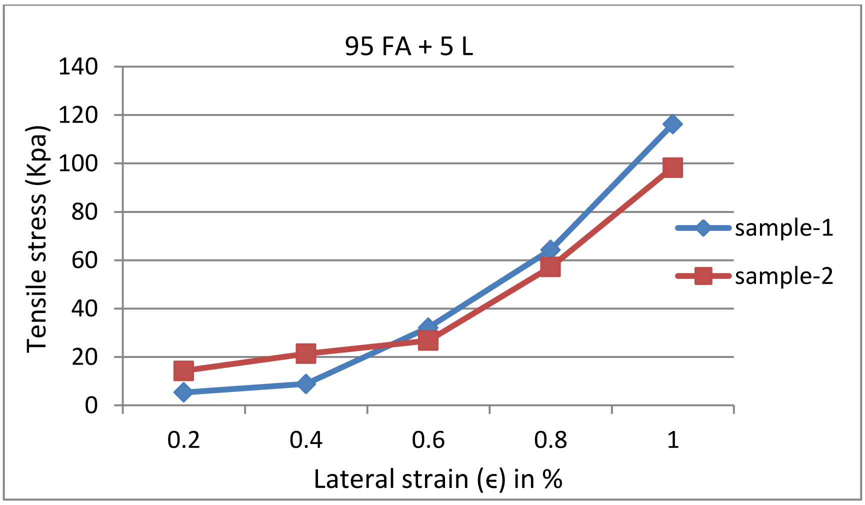

Figure No-4.16 Graph showing plot between stress and strain with 5 % lime of 14 days cured TS sample

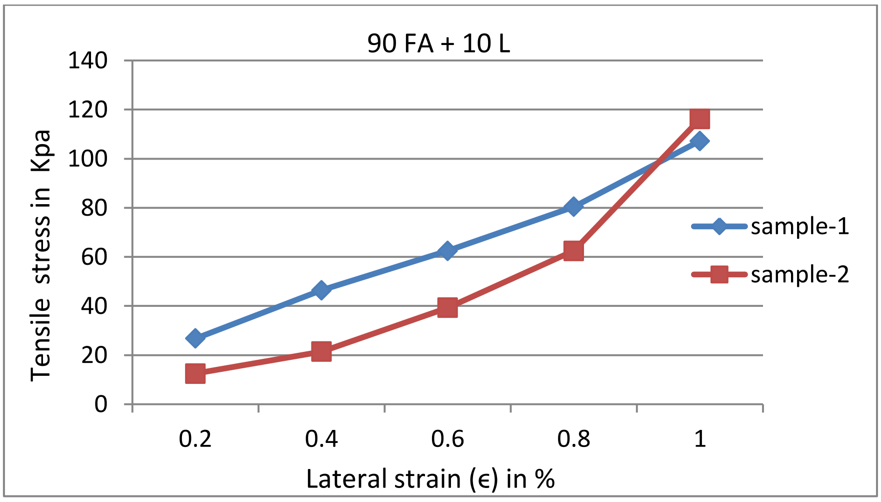

Figure No-4.17 Graph showing plot between stress and strain with 10 % lime of 14 days cured TS sample

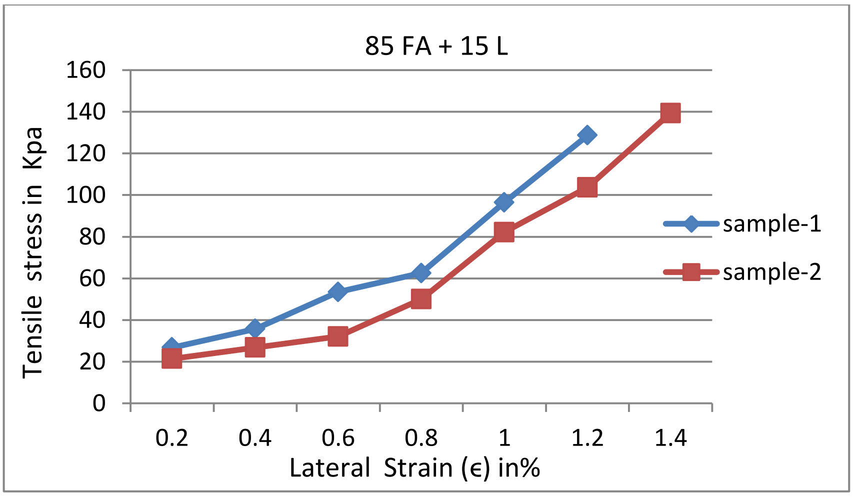

Figure No-4.18 Graph showing plot between stress and strain with 15 % lime of 14 days cured TS sample

21 DAYS CURING

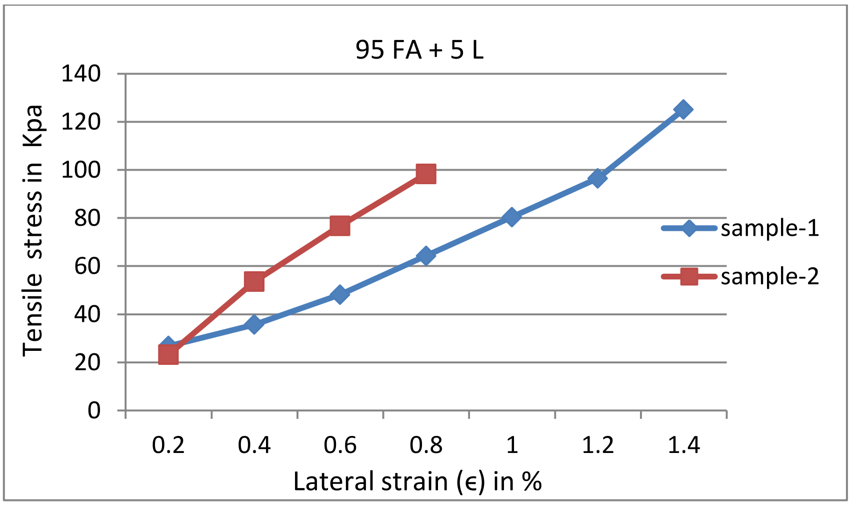

Figure No-4.19 Graph showing plot between stress and strain with 5 % lime of 21 days cured TS sample

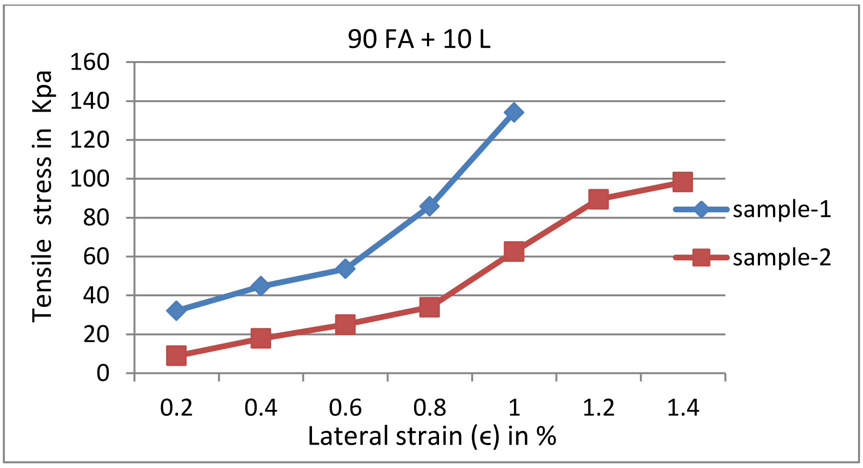

Figure No-4.20 Graph showing plot between stress and strain with 10 % lime of 21 days cured TS sample

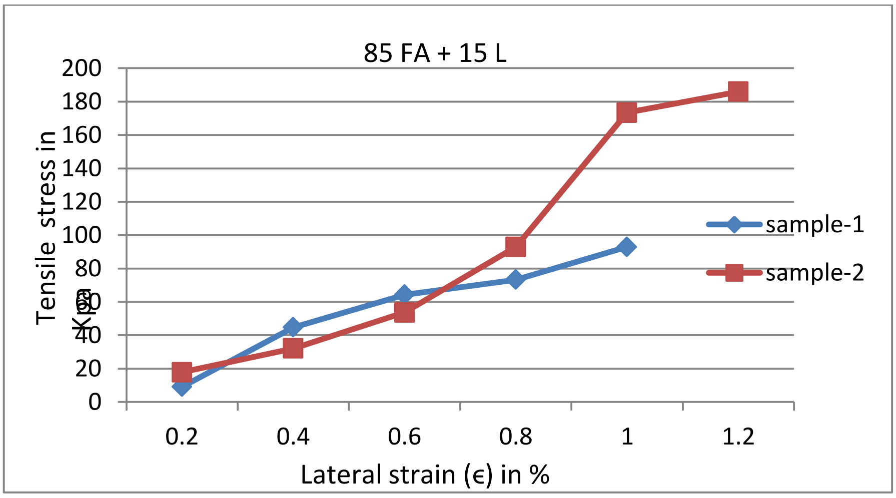

Figure No-4.21 Graph showing plot between stress and strain with 15 % lime of 21 days cured TS sample

The followings graphs plotted between UCS and curing period taking different proportions of lime (5, 10, and 15 %)

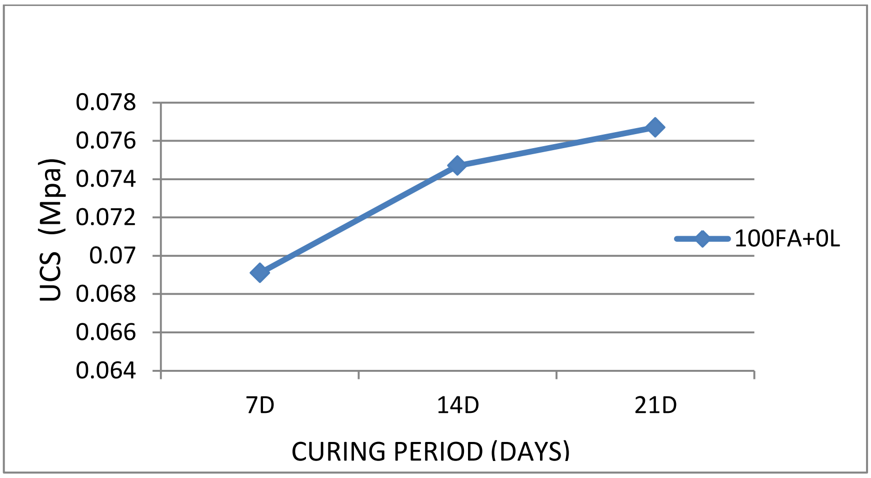

Figure No-4.22 Graph showing plot between UCS and curing days with no lime content samples.

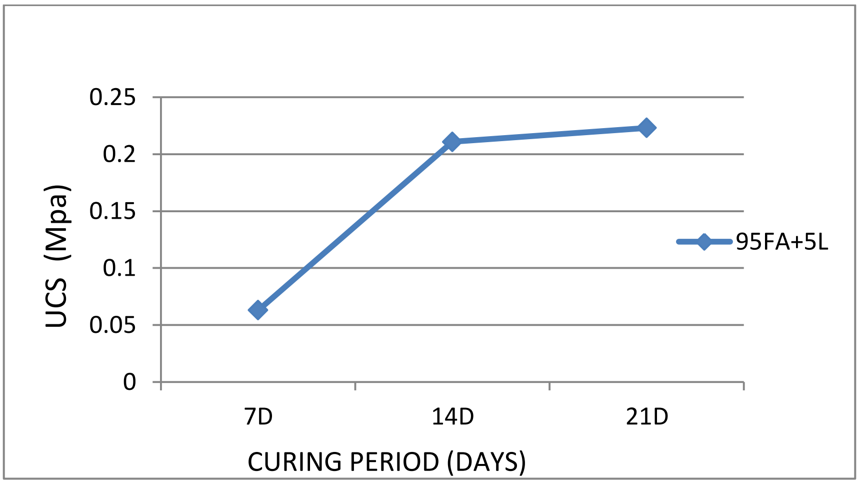

Figure No-4.23 Graph showing plot between UCS and curing days with 5 % lime content samples.

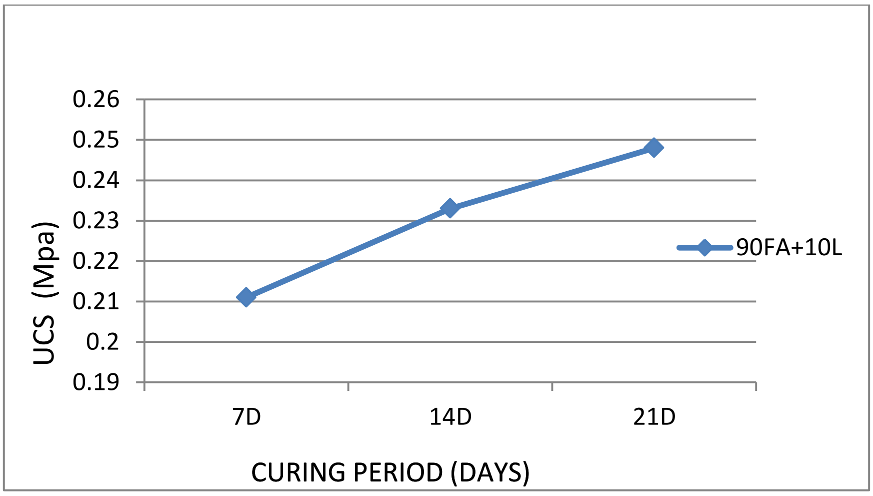

Figure No-4.24 Graph showing plot between UCS and curing days with 10 % lime content samples.

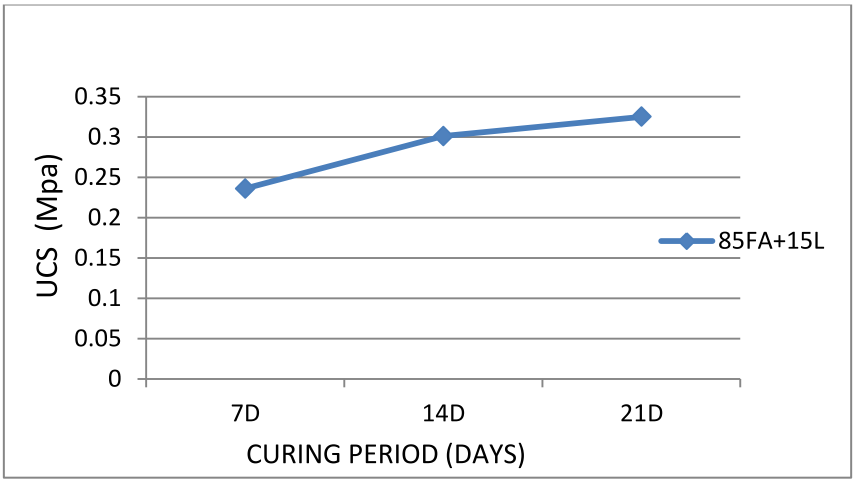

Figure No-4.25 Graph showing plot between UCS and curing days with 15 % lime content samples.

The followings graphs plotted between tensile strength and curing period taking different proportions of lime (5, 10, and 15 %)

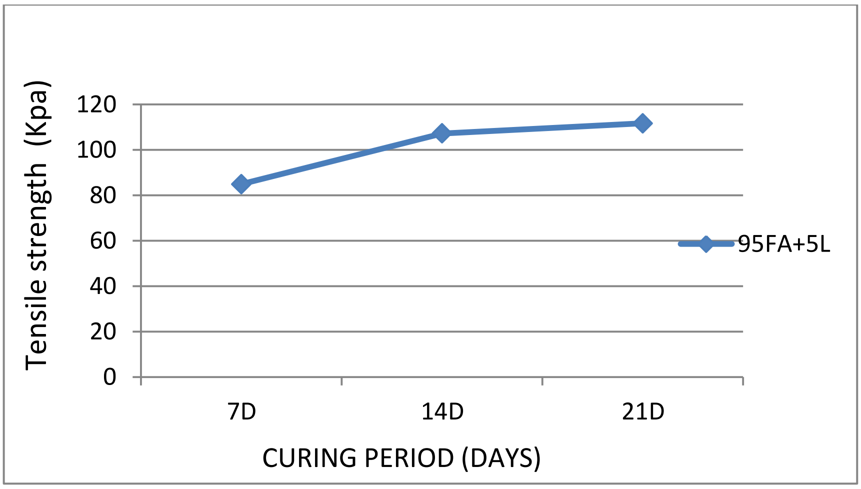

Figure No-4.26 Graph showing plot between TS and curing days with 5 % lime content samples.

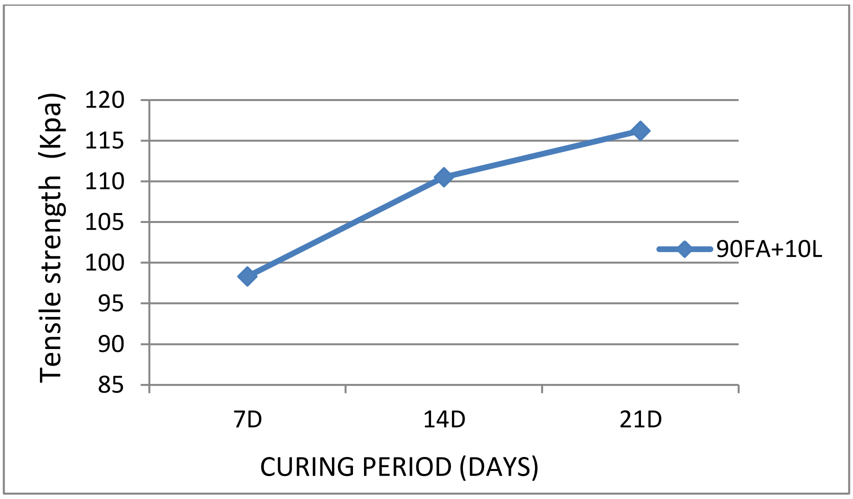

Figure No-4.27 Graph showing plot between TS and curing days with 10 % lime content samples.

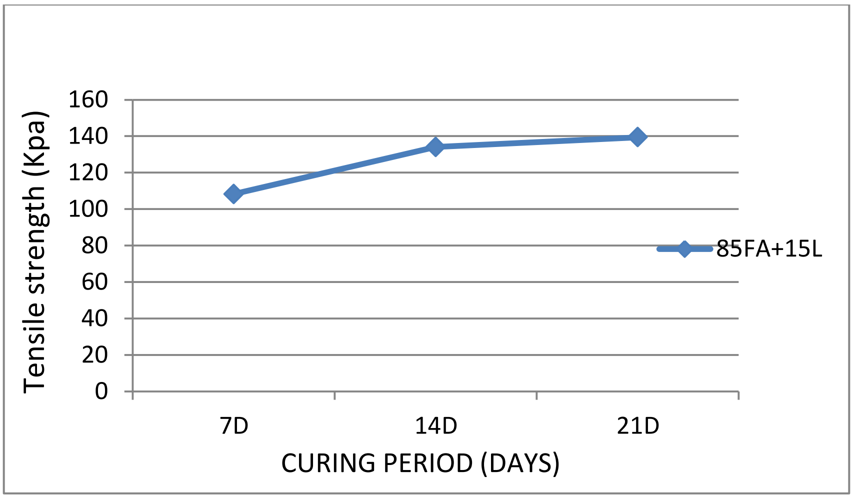

Figure No-4.28 Graph showing plot between TS and curing days with 15 % lime content samples.

The followings graphs plotted between UCS and lime content of different cured sample.

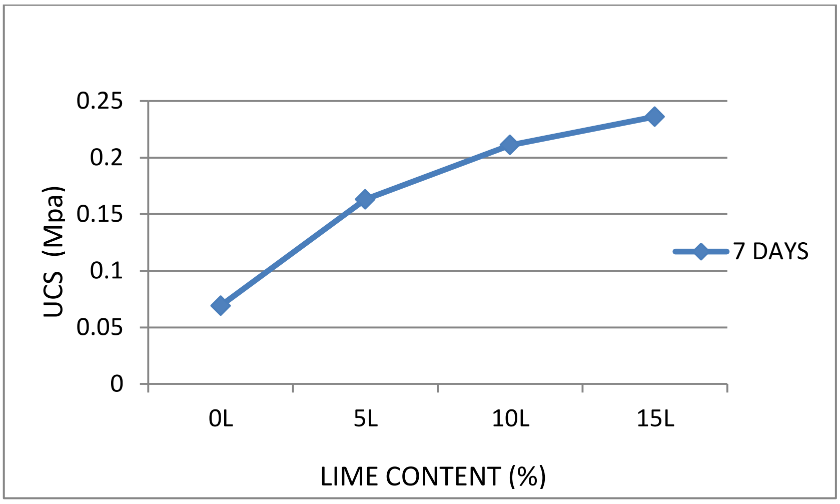

Figure No-4.29 Graph showing plot between UCS and lime content of 7 days cured samples.

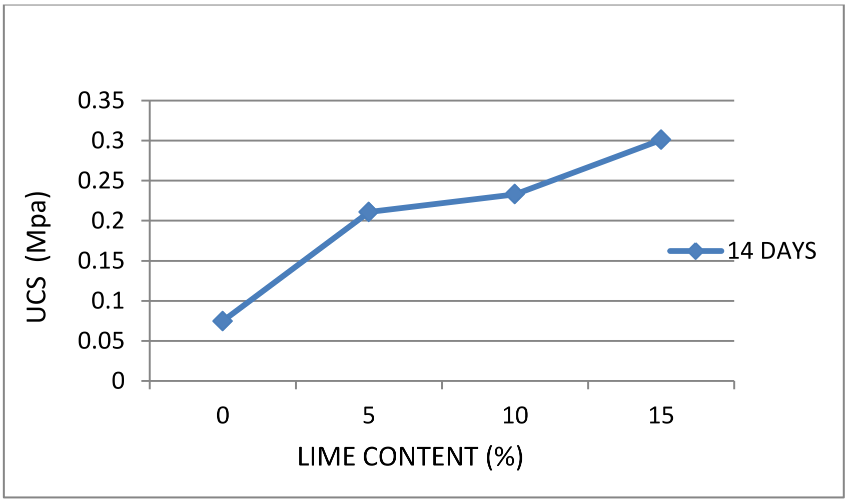

Figure No-4.30 Graph showing plot between UCS and lime content of 14 days cured samples.

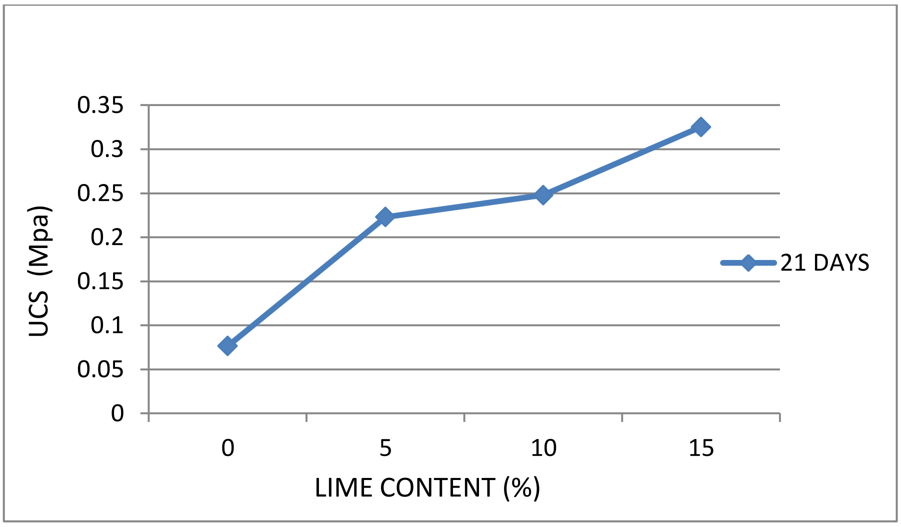

Figure No-4.31 Graph showing plot between UCS and lime content of 21days cured samples.

The followings graphs plotted between tensile strength and lime content of different cured sample.

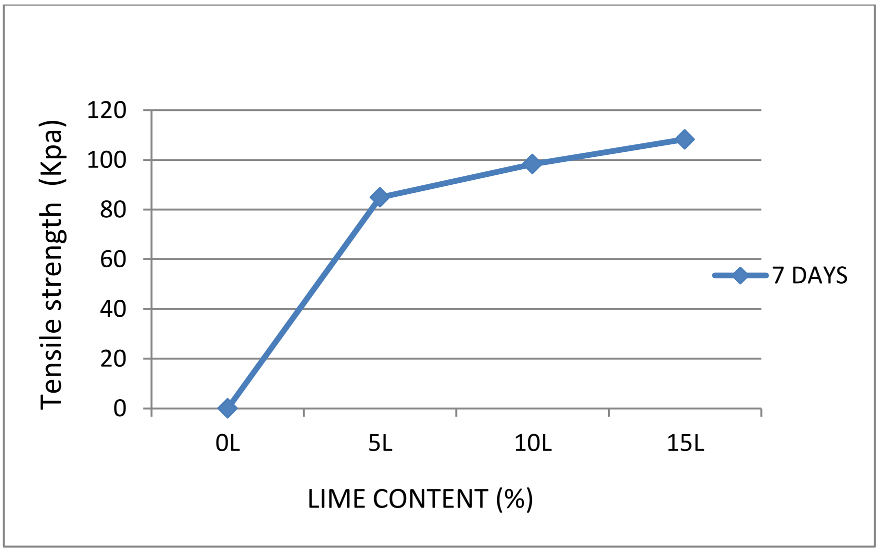

Figure No-4.32 Graphs plotted between tensile strength and lime content of 7 days cured samples.

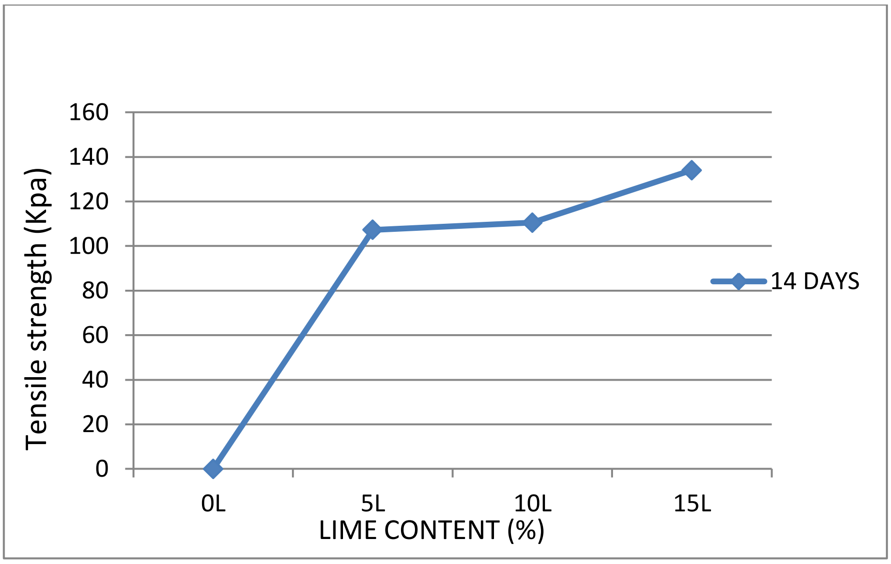

Figure No-4.33 Graphs plotted between tensile strength and lime content of 14 days cured samples.

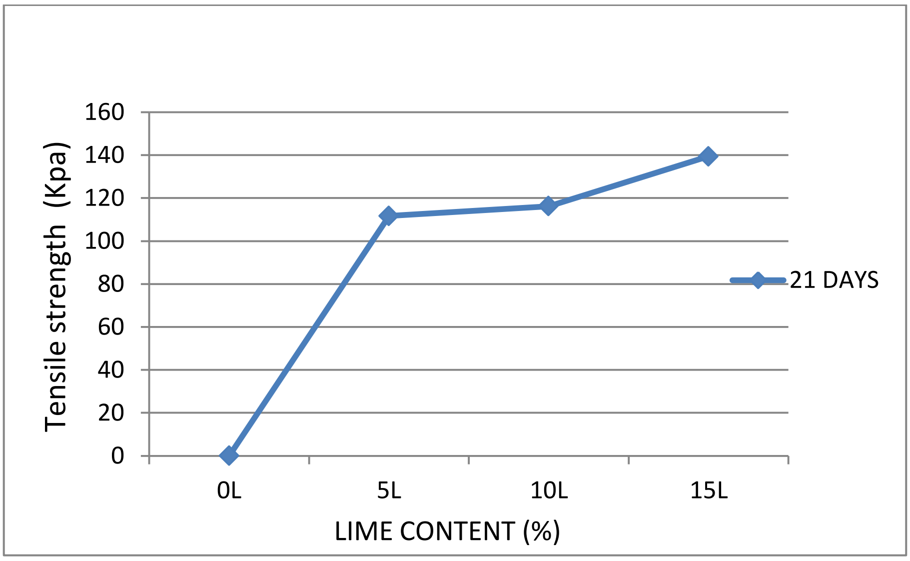

Figure No-4.34 Graphs plotted between tensile strength and lime content of 21 days cured samples.

4.1.2 DISCUSSIONS

Compressive strength test is a measurement of the resistance of the composites to external loading. UCS tests were conducted on fly ash composite(lime 5,10,15 %) for 7 days, 14 days and 21 days curing period at room temperature that was about 30 $\pm 1^{o}$ C. stress and strain curve of different sample were plotted of different curing days. In some stress strain curve there is sudden increase for one deformation and though the loading rate is constant same sample of one composition shows different failure load and different curve because of sample preparation, compaction of sample.

The strength of 7 days cured samples of raw fly ash are very low with only 0.0691 Mpa and a very marginal increase for 14 and 21 days cured samples. The strength increases by 2 times by adding 5 % lime for 7 days curing. For 14 days curing the strength nearly doubles of 7 days cured sample but for 21 days curing the increase in strength is marginal. By adding 10 %lime the strength increases by 20 % and for 15% sample the strength increases by 10 % of sample containing 10 % lime.

For every sample the strength increment is more from 7 days to 14 days curing period and less for 14 days to 21 days curing period.

Tensile strength is a measure of resistance of the composites to external tensile forces. Brazilian indirect tensile strength tests were carried out to determine the tensile strength of the fly ash composites in the same testing machine used to find the compressive strength. The samples for the test measured 50 mm in diameter and 25 mm in thickness were cut from the specimen prepared for compressive strength tests. The samples were loaded along the diametrical axis as mentioned in the method. It was observed that the tensile strength of fly ash without lime has nearly zero tensile strength. The samples with 5 %, 10 % and 15 % lime have strength of 84.9, 98.3 and 108.3Kpa with 7 days curing. The increase in strength from 5% to 10% limes content by 14% whereas from 10 % to 15 % lime is 9 %. For every sample except fly ash with no lime the strength increment is more from 7 days to 14 days curing period and less for 14 days to 21 days curing period.

4.2 FAILURE PROFILE

4.2.1 UCS STRENGTH FAILURE PROFILE

Before testing After testing

Sample-1 sample-2

Figure No -4.35 Failure profiles of 7 days cured UCS sample with no lime

Figure No -4.36 Failure profiles of 7 days cured UCS sample with 5 % lime

Figure No -4.37 Failure profiles of 7 days cured UCS sample with 10 % lime

Figure No -4.38 Failure profiles of 7 days cured UCS sample with 15 % lime

Figure No -4.39 Failure profiles of 14 days cured UCS sample with no lime

Figure No -4.40 Failure profiles of 14 days cured UCS sample with 5 % lime

Figure No -4.41 Failure profiles of 14 days cured UCS sample with 10 % lime

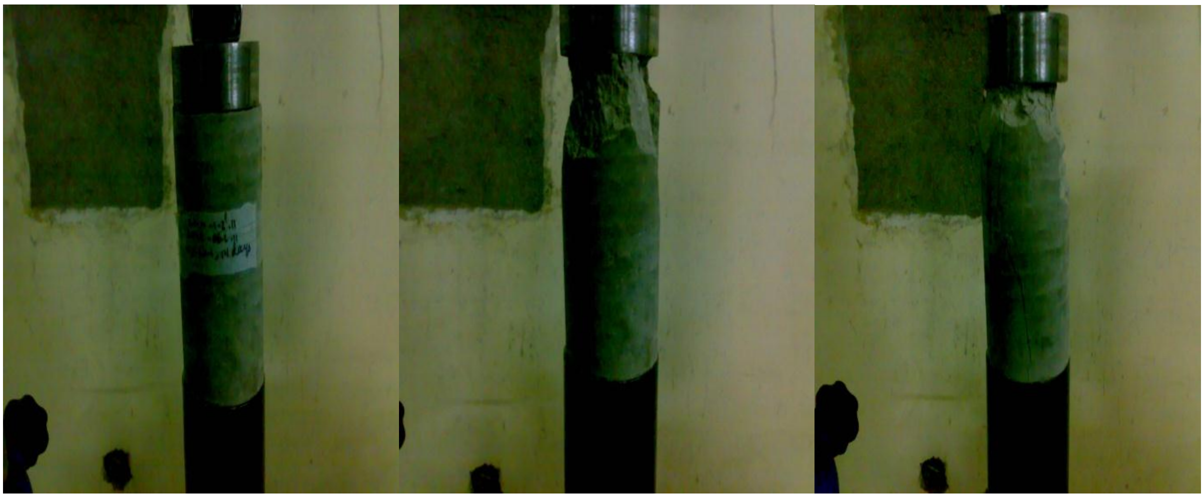

Figure No -4.42 Failure profiles of 14 days cured UCS sample with 15 % lime

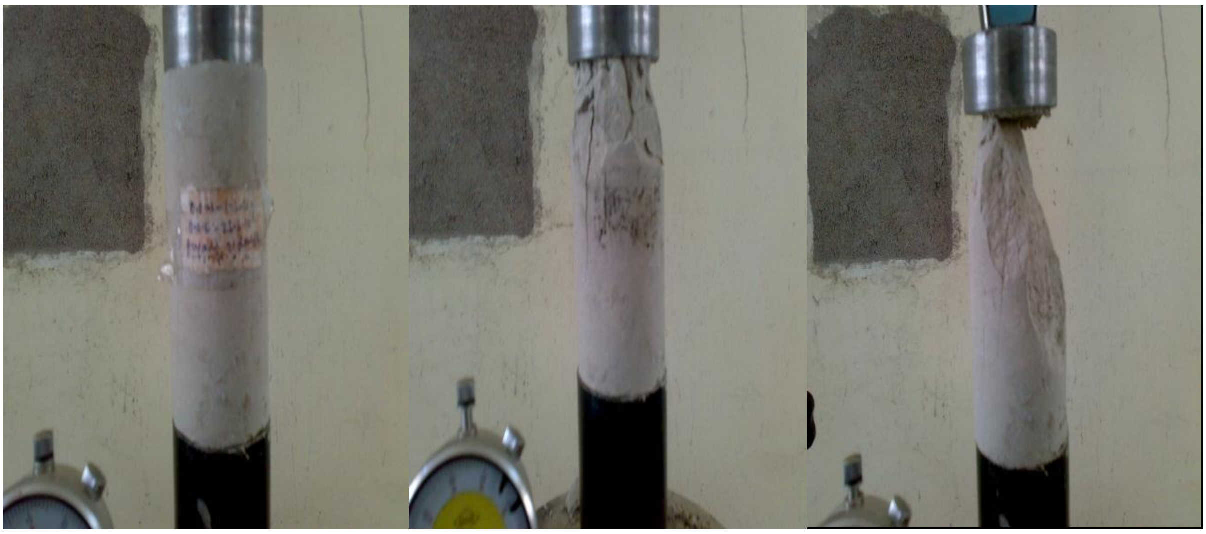

Figure No -4.43 Failure profiles of 21 days cured UCS sample with no lime

Figure No -4.44 Failure profiles of 14 days cured UCS sample with 5 % lime

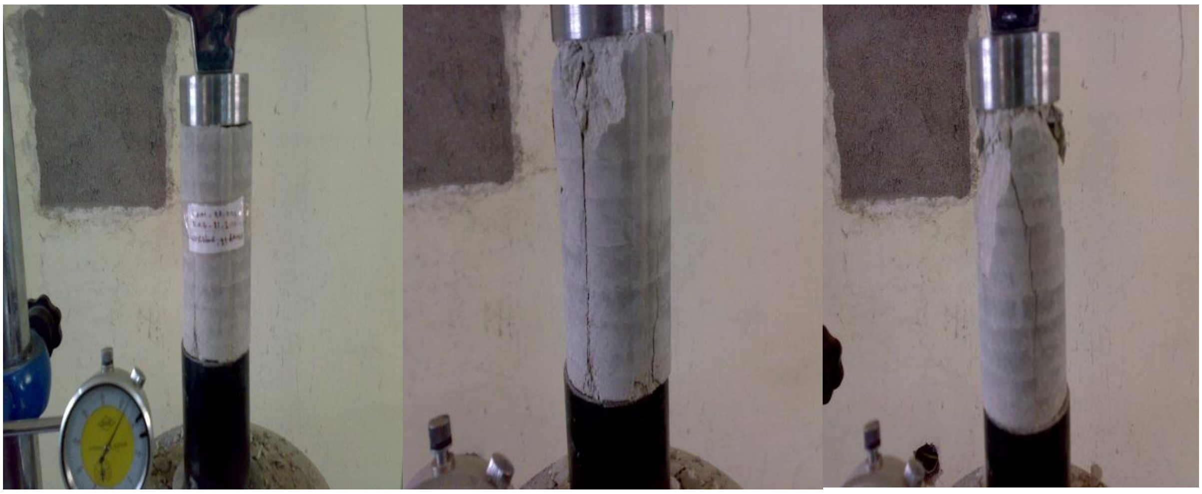

Figure No -4.45 Failure profiles of 14 days cured UCS sample with 10 % lime

Figure No -4.46 Failure profiles of 21 days cured UCS sample with 15 % lime

4.2.2 TENSILE STRENGTH FAILURE PROFILE

Before testing After testing

Sample-1 sample-2

Figure No -4.47 Failure profiles of 7 days cured TS sample with no lime

Figure No -4.48 Failure profiles of 7 days cured TS sample with 5 % lime

Figure No -4.49 Failure profiles of 7 days cured TS sample with 10 % lime

Figure No -4.50 Failure profiles of 7 days cured TS sample with 15 % lime

Figure No -4.51 Failure profiles of 14 days cured TS sample with no lime

Figure No -4.52 Failure profiles of 14 days cured TS sample with 5 % lime

Figure No -4.53 Failure profiles of 14 days cured TS sample with 10 %lime

Figure No -4.54 Failure profiles of 14 days cured TS sample with 15 % lime

Figure No -4.55 Failure profiles of 21 days cured TS sample with 15 % lime

Figure No -4.56 Failure profiles of 21 days cured TS sample with 10 % lime

Figure No -4.57 Failure profiles of 21 days cured TS sample with 5 %lime

Figure No -4.58 Failure profiles of 21 days cured TS sample with no lime

4.3 MOISTURE CONTENT

The moisture content of fly ash collected from NALCO was found to be 2.78 %. Few amount of moisture is present in fly ash.

4.4 TRUE DENSITY

The true density of fly ash collected from NALCO was found to be 2.2.

4.5 SUMMARY:

This study was directed towards evaluation of performance of sample specimen incorporating fly ash in addition to proportion of lime. Sample mixes; contains 420 g of fly ashes is proportioned to have 5, 10, 15 % by weight of fly ash sample. The water to cementitious materials was approximately 20 % by weight of sample, and the desired workability of sample mixes was obtained.

In general, compressive strength increases with age, and decreases with increasing fly ash inclusions in the tested range of variables. However, the specimen containing fly ash in addition to lime is developed to gain maximum compressive strength with age. At an early 7-day age, sample specimen showed a high early compressive strength which is suitable for use in structural concrete.

Based upon data recorded, it can be concluded that specimen containing fly ash with appropriate proportion of certain additives can be proportioned to meet the strength and workability requirement for structural grade concretes.

The chemical, physical and mineralogical properties of fly ash have appreciable effects on performance of fly ash in concrete. Properties of cement influence the performance of concrete. Therefore, it is always necessary to determine the optimum mixture proportions for each, lime, and fly ash source before use.

CHAPTER 5

CONCLUSION

CHAPTER: 05
CONCLUSION

It is observed that as the lime content increasing the strength is also increasing but amount of increase in strength from 5 % to 10% is more and from 10 % to 15% is less. Addition of lime in excess to fly ash may not be beneficial. As the curing period increases the strength also increases. But increase in strength from 7 days to 14 days curing is more than from 14 days to 21 days curing. Up to certain days of curing there will be no more increase in strength.

Based upon data recorded, it can be concluded that specimen containing fly ash with appropriate proportion of certain additives can be proportioned to meet the strength and workability requirement for structural grade concretes and Geotechnical application.

After conducting all the experiments related to strength development of fly ash based composite materials the following are the factors that affect Strength Gain of Lime- -Fly ash composite material:

- Fly ash type (classification, particle size and distribution, etc.)
- Types of stabilization agent/agents
- Preparation of sample
- Sample size (mould size)
- Curing time

FUTURE SCOPE OF STUDY:

Due to self-hardening properties of fly ash they have wide spread application. If more number of samples could have been taken and more days curing period have been taken then it could have given more accurate results. From the above analysis of samples & based on the results obtained, it can be suggested that the Strength of the fly ash composite materials can be further increased by adding the necessary additives in a higher percentage amount & providing them enough curing period for better compaction. For which those composites can fulfil the requirements for construction purposes.

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